THE IMPACT OF TUTOR, EXTRACT AND WORD ON THE CORRECT DEFINITION OF LEXICALLY AMBIGUOUS WORDS IN STATISTICS

Alice Richardson[a], Peter Dunn[b], Rene Hutchins[b]

Presenting Author: Alice Richardson (alice.richardson@canberra.edu.au)
[a]Faculty of Education, Science, Technology and Mathematics, University of Canberra, Canberra ACT 2601, Australia
[b]Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Sippy Downs QLD 4551, Australia

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ABSTRACT
Lexical ambiguity arises when a word from everyday English is used differently, with a specific meaning, in a particular discipline, such as statistics. This paper reports on a project that studies the effect of such words within the context of extracts from scholarly articles on students' ability to define lexically ambiguous words correctly and statistically. The effect of the tutor on students' ability to overcome lexical ambiguity after a one semester introductory Statistics course is also studied.

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INTRODUCTION
In the transition from everyday conversation to scientific conversation, students are often confronted with words with one meaning in common English usage and another, more specific, scientific meaning. Part of their training is to learn the scientific meaning of these 'lexically ambiguous' (Barwell 2005; Kaplan, Fisher, & Rogness 2009, 2010) words. This ambiguity creates a mystique about a subject (Lemke 1990), which can make the subject appear more difficult than it really is, and more difficult to master than necessary.

This phenomenon has been studied in several scientific disciplines. Thompson and Rubenstein (2000) list twelve potential pitfalls in mathematics vocabulary, including "some words [that] are shared by mathematics and everyday English, but… have distinct meanings". They give examples for each, including some statistical terms such as 'average', 'outlier' and 'range'. Tomlinson, Dyson, and Garratt (2001) identified twelve terms with which students were expected to be familiar when working with uncertainty in data (not necessarily statistics in general; their students' background is chemistry). These twelve terms were identified through discussions with "a number of concerned colleagues" including the terms 'precise', 'accurate', 'sensitive', and 'significant difference'. The authors then rated the responses from 33 chemistry students as either showing "good or some understanding", or "little or no understanding". In other science disciplines such as biology, chemistry and genetics, the language is so specialised as to appear like a foreign language to students. Strategies normally used to teach a foreign language have been applied to these sciences (Zhang, Lidbury, Richardson, Yates, Gardiner, Bridgeman, Schulte, Rodger, & Mate, 2012).

Our work focuses on first-year undergraduate students, and specifically their written communication of the meaning of words. Parke (2008) discusses ideas for teaching written statistical communication to graduate students, while Lavy and Mashiach-Eizenberg (2009) research oral communication. Kaplan et al. (2009, 2010) listed 36 lexically ambiguous words, chosen by "brainstorming" within the research team. Their research then focused on these five words: 'association', 'average', 'confidence', 'random', 'spread'. They first reported on the definitions and uses that students made of words at the beginning of semester, from students studying at two universities in the midwestern United States. The latter paper reported on how students responded at the end of an undergraduate statistics course: the authors found that many students still could not use the five words studied by the authors correctly in statistical English. For example, they state that it is "particularly discouraging that, in the validation sample, only 5% of the subjects were able to correctly define the word *random* as used in a statistical sense” (Kaplan et al., 2010). The authors then discuss implications for teaching; as an example, Kaplan et al. (2010) discuss definitions for the word ‘spread’

> ... such as a vast area, a coverlet, and a buffet of different food items. Given the number of existing definitions for *spread*, the choice of this word as a colloquialism for the statistical term of *variability* or *scale parameter* is perhaps a poor one. We suggest that instructors use the technical word, *variability*, in classes and dispense with the word *spread*.

Essentially, they argue that the lexically ambiguous terms should be avoided for more specific words (see Kaplan et al., 2010) for more on the use of the word “spread” and recommendations on the use of synonyms). However, as the authors acknowledge, using different terminology is not always possible for every word, and such words represent a “greater challenge”. They offer some advice for using these other words.

Kaplan et al. (2009) devised a list of 36 lexically ambiguous words, but their list is not comprehensive, and nor is it claimed to be. For example, Tomlinson, Dyson, and Garratt (2001) identify different words, and neither list includes “regression”, a word we would identify as lexically ambiguous. This study extends those of Kaplan et al. (2009, 2010) and Tomlinson et al. (2001) in several directions. Firstly, Kaplan et al. (2009) state that students were given a word (such as “association”), and asked to both (a) define or give a synonym for the word, and (b) use the word in a sentence. Tomlinson et al. (2001) use open-ended questions to encourage students to define ambiguous terms. We prefer not to follow this approach of asking for definitions when the statistical meaning is not actually requested and no context is explicitly provided to assist in constructing the definition. Consequently, in this project the research team decided that, instead of asking students to define words free of context, students would be asked to define words when specifically used in the statistical context of a journal article extract. The aim of this project is to determine some of the factors that are important in overcoming lexical ambiguity.

Some specific interventions during the semester were used to assist students in breaking down lexical ambiguities. These interventions were based on the language activities of Zhang et al. (2012), and include strategies (ranging from small group work, online language exercises, role plays and stimulus questions) that have been shown to improve student grades, retention and satisfaction in introductory science courses. The details, impact and evaluation of these interventions on lexical ambiguity in statistics courses will be reported on elsewhere. Unevaluated strategies to overcome ambiguities have also been reported by Thompson and Rubenstein (2000).

BACKGROUND

This study was conducted at the University of the Sunshine Coast (USC), a small Australian regional university (810 enrolments in 2012). The students involved in this study were all enrolled in the course SCI110 *Science Research Methods*, a course that introduces research methodology and statistical concepts. In 2012, students in SCI110 were enrolled in disciplines such as biomedical science, engineering, environmental health, environmental science, health promotion, nutrition and dietetics, occupational therapy, paramedic science, and sport and exercise science. For all students, SCI110 is a required course in their study, usually in their very first semester at university, so many students are not intrinsically motivated to engage with the course. Dunn, Richardson, McDonald, and Oprescu (2012, 2013) discuss other projects conducted to encourage student engagement in SCI110.

METHODS

The course SCI110 is large, with 762 students in 2012. In the first teaching week of the semester (in a 13-week teaching semester), the SCI110 students were presented with extracts from journal articles. The research team identified extracts from journal articles in some of the disciplines relevant to the SCI110 students, and highlighted certain lexically ambiguous words in the extract (Table 1). Tutors then asked students to define these words in the given statistical context. Only a small subset of the terms identified by Kaplan et al. (2009) are utilised for this task.

These extracts were presented to the students in teaching week 1, before any of these terms were used or defined in SCI110, so the task evaluated the students' understanding on entry, *before* any course input. On pre-prepared forms, students were asked to write a synonym or definition of the highlighted words as used in the given context. Each student was shown two extracts, with two or three terms highlighted (Table 1). The full text of each extract follows the table.

Table 1: Seven extracts labelled A – D, R – T, with lexically ambiguous words highlighted.

<table>
<tr><td>Extract</td><td colspan="3">Terms highlighted in extract</td><td>Number of tutors
(Number of classes)</td></tr>
<tr><td>A</td><td>Associations</td><td>Relationship</td><td>Significant</td><td>2 (10)</td></tr>
<tr><td>B</td><td>Average</td><td>Associated</td><td></td><td>2 (11)</td></tr>
<tr><td>C</td><td>Control</td><td>Mean</td><td>Intervention</td><td>2 (11)</td></tr>
<tr><td>D</td><td>Correlation</td><td>Randomised</td><td>Significant</td><td>3 (13)</td></tr>
<tr><td>R</td><td>Average</td><td>Association
(positive)</td><td>Significant</td><td>2 (4)</td></tr>
<tr><td>S</td><td>Control</td><td rowspan="2">Correlated</td><td>Intervention</td><td>2 (11)</td></tr>
<tr><td>T</td><td></td><td>Significant</td><td>1 (2)</td></tr>
</table>

A. Kunutsor and Powles (2010). **Associations** between ambient temperature and blood pressure have been demonstrated in countries where the temperature varies between the seasons… There was a **significant relationship** between ambient temperature and systolic and diastolic blood pressure.
B. Hashimoto, Futamura, Nakarai, and Nakahara (2001). Alcohol intake was recorded as the **average** daily amount. The weekly frequency of drinking was **associated** with HDL-cholesterol, but not with triglycerides, total cholesterol, or blood pressure.
C. Venn, Perry, Green, Skeaff, Aitken, Moore, Mann, Wallace, Munro Bradshaw, Brown, Skidmore, Doel, O'Brien, Frampton, and Williams (2010). Fiber intakes were higher, intakes of several vitamins and minerals were better maintained, and dietary glycemic index was lower in the **intervention** compared with the **control** group. **Mean** weight loss at 6 months was 6.0kg and 6.3kg in the control and intervention groups, respectively.
D. Myers, Godwin, Dawes, Kiss, Tobe, Grant, and Kaczorowski (2011). No **significant** differences existed in the characteristics of the patients **randomised** to the two groups. Automated office blood pressure readings also showed a stronger **correlation** with the awake ambulatory blood pressure than did manual readings.
E. Knechtle, Knechtle, Rosemann, and Senn (2011). Results of the multiple regression analysis revealed a negative association between **average** speed in training with race time. There was a **significant** positive **association** between 100-km race time and personal best time in a marathon.
F. James, Smith, Smith, Kirby, Press, and Doherty (2009). Statistical analysis revealed no significant changes between the **control** and **intervention** groups for attitude to engage in physical activity. A higher volume of walking was significantly **correlated** with a more positive attitude to engage in physical activity.
G. James et al. (2009). Statistical analysis revealed no **significant** changes between the control and intervention groups for attitude to engage in physical. A higher volume of walking was significantly **correlated** with a more positive attitude to engage in physical activity.

So in contrast to Kaplan et al. (2010) this study placed the word in a statistical context, and perhaps this provided the students with a context for giving a definition of the type being sought. Research shows the context of words is important in related subjects such as mathematics; for example, see Clark (1994).

In the final teaching week (Week 13), the same extracts were then shown to the students as in week 1, and the same task repeated. In most cases, the same extracts were shown in the same classes, so that most students were exposed to the same extracts in week 13 as in week 1. However, for a number of reasons, this was not always the case. Between weeks 1 and 13, two SCI110 tutors had left: the two tutorials of Tutor 8 were taken by existing Tutors 4 and 6, while a new tutor was employed to take the tutorial of Tutor 9. Furthermore, many students swapped tutorials, dropped the course, or added the course, between weeks 1 and 13.

Table 2: Five example responses in each category for "significant" and "randomised".

Significant	
Statistical and correct (1)	a result has a p value of less than 0.05, not believed to be due to chance e.g. p-value < 0.05 Statistics have been done to demonstrate e.g. p-value Very strong evidence either supporting or rejecting the hypothesis stated a substantial difference or no difference >0.1 or < 0.001
Statistical, but incorrect (2)	evidence in a result p value < 0 p-value >/< values of great importance
Ambiguous (3)	above average describing word true meaning of value important to the equation e.g. significant figure having meaning in terms of numbers not insignificant
Non-statistical but correct (4)	important meaningful definite a result that stood out for some reason or other stand out item, place or thing
Non-statistical and incorrect (5)	drastic distinct relevant certain special big moment
Randomised	
Statistical and correct (1)	selecting without order or pattern selecting unknowingly in some type of pattern selected not in an order selected without preference not pre-meditated
Statistical, but incorrect (2)	scattered selected without reason a random selection to pick something at random a group of people chosen at random
Ambiguous (3)	no bias no one calculated obtusely picked mixed up/different
Non-statistical but correct (4)	things that have nothing to do with each other not connected at all different things can happen out of the blue spontaneously chosen not strategically picked
Non-statistical and incorrect (5)	separated not often anywhere fickle the style in which something is chosen or selected on unjustified uncalculated way

Students recorded their definitions of the terms on provided forms in teaching weeks 1 and 13. This paper focuses on week 13, in order to study the factors that contribute most to students' successful definition of terms. In total, 332 students responded in teaching week 13. (The week 13 tutorials—in the final teaching week—are perceived by students as revision tutorials, and hence not as important as earlier tutorials; consequently, attendance is always low in Week 13.) These responses were transcribed to a spreadsheet, and each of these student-supplied definitions was then scored into one of the following coding categories: Statistical and correct (coded as 1); Statistical, but incorrect (coded as 2); Ambiguous (coded as 3); Non statistical but correct (coded as 4); Non statistical and incorrect (coded as 5); and No response (coded as 6). Overall, 1825 definitions were provided by students of which 1125 (62%) were statistical and correct. Table 2 shows examples of some student responses and how they were categorised.

Two experienced statistics lecturers (the first two authors) and a research assistant (a tutor and experienced teacher; the third author) scored a sample of 95 of the responses independently, and all were blinded to the class. The scoring was relatively generous, given that the students had a small amount of space in which to write their responses, and the responses were not being graded (so students could not be expected to treat the task with the same diligence as a graded assessment task).

RESULTS

The focus of this article is the nine words used in the extracts. Our purpose is to study the impact of the Extract and the Tutor; the allocation scheme of words within extracts to tutors allows for a nested structure consisting of Tutor, Extract, and Word within Extract to model the probability of a correct definition. Implicit in this model is that all students have also received one semesters' instruction in introductory statistics. Not every tutor kept their different classes' data separate, so it is not possible to nest class within tutor in this analysis. The response variable is measured on a six-level categorical scale, but for this analysis the scale was collapsed to two categories: statistical and correct (recoded as 1); and other (coded as 0); thus the "other" category includes categories 2 – 6 from the original scoring.

Since we wish to study the effect of several predictors on a binary response, a logistic regression model will be fitted to the data (Hosmer & Lemeshow, 2000). The assumptions required by the model are that the response is binary; and that there are several predictors, which need not follow a Normal distribution.

In Table 3, an analysis of deviance for the factors Extract, Tutor, and Word within Extract is shown. In Table 4, the parameter estimates, standard errors, asymptotic *z* statistics and asymptotic *p* values are shown. Analysis was conducted using R (R Core Team 2013).

Table 3: Analysis of deviance for logistic regression of correct definition on Tutor, Extract and Word. Terms were included in the model in the order shown.

Model	Df	Deviance	Resid. Df	Resid. Dev
NULL			1825	2530.0
Tutor	7	238.81	1818	2291.2
Extract	6	110.36	1812	2180.8
Extract:Word	12	493.62	1800	1687.2

DISCUSSION

SIGNIFICANCE OF TUTOR

The effect of tutor is highly significant ($X^2 = 238.81$, df = 7, $p < 0.0001$). The tutorials that fared the worst had one tutor leave and another take over part-way through semester, indicated by the label "mixed" in Table 3. This disruption may well have contributed to the poorer scores. Note that tutors were not allocated to tutorials at random, but rather according to their timetabling and outside-work requirements. Students enrolled in whichever tutorials they wished, but generally students from similar programs enrolled in tutorials according to their other timetabling requirements. In summary, the allocation of students to tutors depends on factors not included in the model, which could be pursued in future research.

It is also not possible to tell, from the data we have, whether the tutors who took the "mixed" tutorials were simply not as good in their roles as compared with the other tutors. The "mixing" involved both a situation where a tutor left and a new one was employed; and a situation where a tutor left and an existing tutor took on the extra tutorial. If these two situations are explicitly included in the model, there is a small shift in significance (the class taken over by the existing tutor performs slightly worse than the new one). However more research would be required to discover whether factors such as tutor experience, the way tutors administered the task, and the number of classes taken, are confounding the results seen here.

Table 4: Parameter estimates, standard errors and *t* values for logistic regression of correct definition on Tutor, Extract and Word. Six tutors who taught the same classes all semester are numbered 1 to 6, and other classes where there was a disruption to the tutor were all combined and denoted "mixed". Significance codes: * means p < 0.5, ** means p < 0.01, * means p < 0.001.**

	Estimate	Std. Error	z value	Pr(>|z|)	
Tutor 1	2.559	1.124	2.278	0.0227	*
Tutor 2	0.678	0.379	1.789	0.0736	.
Tutor 3	3.033	0.972	3.122	0.0018	**
Tutor 4	0.897	0.220	4.070	<0.0001	***
Tutor 5	0.054	0.591	0.091	0.9277	
Tutor 6	-0.355	0.583	-0.608	0.5431	
Tutor mixed	-0.999	0.550	-1.818	0.0691	.
Extract A					
Baseline word: association					
relationship	-0.186	0.306	-0.610	0.5420	
significant	-5.221	0.815	-6.408	<0.0001	***
Extract B	2.097	0.619	3.389	0.0007	***
Baseline word: association					
average	-0.922	0.321	-2.868	0.0041	**
Extract C	-0.034	1.172	-0.029	0.9768	
Baseline word: significant					
control	-0.867	0.520	-1.667	0.0955	.
intervention	-1.117	0.507	-2.206	0.0274	*
Extract D	-4.295	0.557	-7.713	<0.0001	***
Baseline word: significant					
correlation	4.771	0.550	8.670	<0.0001	***
randomised	3.907	0.539	7.254	<0.0001	***
Extract R	1.958	0.721	2.716	0.0066	**
Baseline word: association					
average	-2.166	0.690	-3.138	0.0017	**
significant	-5.407	0.950	-5.691	<0.0001	***
Extract S	1.688	0.607	2.780	0.0054	**
Baseline word: intervention					
control	0.000	0.320	0.000	1.0000	
correlation	-0.285	0.309	-0.922	0.3565	
Extract T	-4.272	1.171	-3.650	0.0003	***
Baseline word: significant					
correlation	2.406	0.412	5.839	<0.0001	***

The model is highly significant (X^2 = 842.8, df = 25, p < 0.0001) and Nagelkerke's R-squared is 0.49.

SIGNIFICANCE OF EXTRACT

The effect of extract is highly significant (X^2 = 110.36, df = 6, p < 0.0001), after adjusting for tutor. Compared to Extract A, Extracts B, R and S are handled the best and Extracts D and T are handled the worst. There does not appear to be a pattern uniting these extracts. Extracts B, R and S are from a mixture of sports and nutrition journals. Indeed extract S (handled well) and T (handled poorly) highlight different words from the same extract, indicating the importance of the interaction between extract and word.

Future work on lexically ambiguous words in context could help to uncover why it is that extract is so significant in this model. Most other research is taking words out of context, and we expect ground-breaking work in this area would need to take note of the literature on language acquisition; see for example Zhang et al. (2012). Interventions designed to combat lexical ambiguity based on the small-group and online activities described in Zhang et al. (2012) have been trialled by the authors, and will be reported in future publications. Research could also focus on whether abstracts from a student's own discipline reduce lexical ambiguity.

SIGNIFICANCE OF WORD WITHIN EXTRACT

The effect of word within extract is highly significant ($X^2 = 493.62$, df = 12, $p < 0.0001$). The word "significant" is handled very badly even at the end of semester, consistent with the findings of Kaplan et al. (2010). The words "randomised" and "correlation" are in general handled the best. This is in contrast to Kaplan et al. (2010) who found that only 11% of subjects gave a correct statistical definition of the word "random" at the end of semester. Note however that our word is in context, and in the form "randomised" rather than "random".

CONCLUSION

In this paper, we gathered data from students which highlight factors that affect their understanding of lexically ambiguous words in statistics as identified by Kaplan et al. (2009), at the end of one semester of introductory statistics study. Our methodology places the words in the context that students are likely to meet them, adding an authentic aspect to the assessment of lexical ambiguity. The results showed that tutor, extract, and word within extract all had a statistically significant effect on students' correct definition of lexically ambiguous words. This suggests that students making the transition from everyday conversation to scientific conversation benefit from the consistency of a small number of academic staff, as well as exposure to a variety of lexically ambiguous words in a variety of contexts.

Increasing students' understanding of lexically ambiguous words is important, and more work should be invested in how to enhance students' understanding of lexically ambiguous words. Zhang et al. (2012) discuss and evaluate many types of interventions for assisting with more general language acquisition issues in science, by drawing on methods used in the teaching of foreign languages (p. xiii). Dunn et al. (2012, 2013) implement and evaluate classroom response systems as one example of an intervention. Investigating how well other interventions work in the statistics classroom is an avenue for further research.

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